Applying High-Speed Profiler and Automated Pavement Distress Survey System in Pavement Maintenance Prioritization

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ABSTRACT

Pavement maintenance prioritization is mainly based on roughness index and pavement distress index in many countries. Three-meter straightedge has been used as a standard instrument for measuring the newly constructed and rehabilitated pavements in Taiwan for decades, and the corresponding measured values, such as the standard deviation and maximum hump and dip, are also used as the smoothness acceptance specification. In addition, Pavement Condition Index (PCI) is widely used as distress index. Three-meter straightedge and PCI are conducted by manual survey, which is very costly, time-consuming, and labor-intensive, so it is almost impossible to apply it on a large scale roadway network periodically. Therefore, due to the lack of pavement performance data, pavement maintenance prioritization cannot be executed completely and effectively.

Recently, many developed countries tend to adopt automatic equipments for pavement condition survey to enhance the efficiency, such as high-speed profiler and automated pavement distress survey system. High-speed profiler and roughness index International Roughness Index (IRI) has been popularized for years, and automated pavement distress survey system is also developing.

Hence, this study investigated 570 lane-km pavement conditions in city streets with high-speed profiler and automated pavement distress survey system synchronously. Following the results, the present pavement conditions are analyzed and presented; the pavement maintenance prioritization for network level is also suggested.

1. INTRODUCTION

Pavement maintenance prioritization is mainly based on roughness index and pavement distress index in many countries. Three-meter straightedge has been used as a standard instrument for measuring the newly constructed and rehabilitated pavements in Taiwan for decades, and the corresponding measured values, such as the standard deviation and maximum hump and dip, are also used as the smoothness acceptance specification. However, with the development of high-speed profiler and the popularization of IRI in recent years, some

agencies also tend to adopt IRI as the roughness index in Taiwan.

In Taiwan, road authorities use pavement condition indices to evaluate pavement condition. However, PCI is conducted by manual survey, which is very costly, time-consuming, and labor-intensive [1], so it is almost impossible to apply it on a large scale roadway network periodically. Therefore, the complete PCI data of city streets in Taiwan are still not available, and due to the lack of pavement performance data, pavement maintenance prioritization cannot be executed completely and effectively.

Since 1970, the basic idea of automated pavement condition survey system has been proposed to eliminate the influence of traffic. [2]. Therefore, several attempts have been made to develop an automated procedure, and most current systems use computer vision and image processing technologies to automate the process [3] . There are three kinds of imaging instrument used in the automated pavement condition survey system, includes line-scan camera, area-scan camera, and laser system. Due to the higher expense of laser system, most suited automated pavement condition survey vehicles adopt line-scan or area-scan camera to acquire the pavement condition data.

The critical restriction of automated pavement condition survey system is the high price. However, Cline[4] evaluated the expenses of manual survey and automated pavement condition survey, and found when performing the large scale survey, the average costs are very close (US$ 0.13/m^2 for manual and US$ 0.12/m^2 for automated survey). Therefore, the automated pavement distress survey system is also popularized in Taiwan recently.

When integrating the roughness index and pavement distress index to prioritize the maintenance roads, maintenance agencies from all over the worlds adopts different indices, and the considerations differ. So far, Maintenance Control Index MCI is wildly used in national highway in Japan, and is also adopted by some local maintenance agencies; Pavement Quality Index PQI is widely used in Minnesota; maintenance agencies in South Carolina adopt Pavement Quality Index PQI to quantify the pavement performance; Chinese government has announced the standard of using Maintenance Quality Indicator MQI to evaluate the pavement conditions in 2007.

Both of the above indices combine different kinds of pavement performance and the considerations. Most of the indices take roughness, distress, and rutting into account; the roughness is represented by IRI, and the rutting is represented by the average depth; when quantifying the distress condition, some of the agencies adopts the cracked percentage (such as the Maintenance Control Index in Japan) and some adopts weighted deduction value (such as Pavement Quality Index in Minnesota and Maintenance Quality Indicator in China).

However, prior to establish the integrated index to prioritize the maintenance roads, the present performance of city streets should be investigated, which includes the roughness and distress. Hence this study investigated 570 lane-km pavement conditions in city streets with high-speed profiler and automated pavement distress survey system synchronously. Following

the results, the present pavement conditions are analyzed and presented.

2. EQUIPMENT [5][6]

This study utilized high-speed profiler and automated pavement distress survey system to collect the pavement data. The adopted high-speed profiler in this study was invented by National Taiwan University. The main components include accelerator, Distance Measurement Instrument (DMI), and height sensor. This high speed profiler collects the profile of roads in high speed, with the suited software the corresponding IRI value will be calculated.

The automated pavement distress survey system PicCrack was developed by NNW, Inc. in America. The components of PicCrack system are vehicle, note book, area-scan camera, Distance Measurement Instrument (DMI), and suited software. The frame of the camera was designed and completed in cooperate with Department of Mechanical Engineering at National Taiwan University. Figure 1 shows the appearance of PicCrack system. When collecting the pavement data, the camera acquired the pavement images according to the DMI, and the acquired images will be inputted and analyzed by the suited software.

The PicCrack system adopts Unified Crack Index (UCI) as the pavement distress index to quantify the pavement condition. UCI was proposed by Pavement Management Implementation (ASTM STP 1121). It is based on the image tiles to quantify the percentage of non-cracked area without considering the crack type; the range of UCI is from 0 to 100, the higher the UCI represents the better condition of pavement, and the lower the UCI represents the worse condition of pavement. Figure 2 shows the calculation logic of UCI; the image will be divided into tiles and analyzed by its gray scale; the following section will compare the difference and the relationship between UCI and PCI.

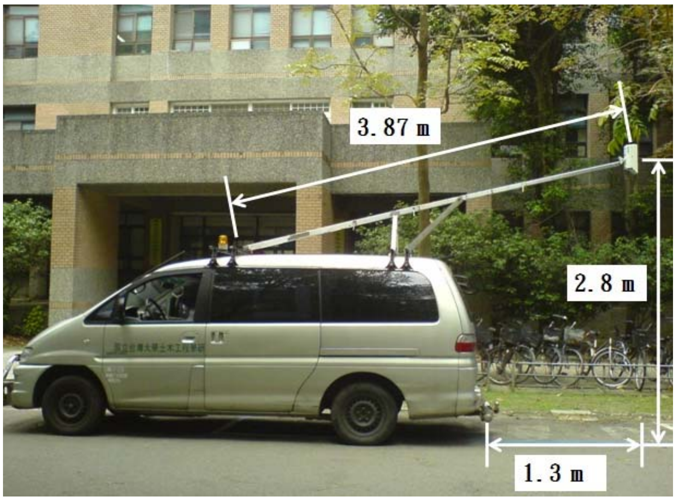

Figure 1. Appearance of PicCrack system.

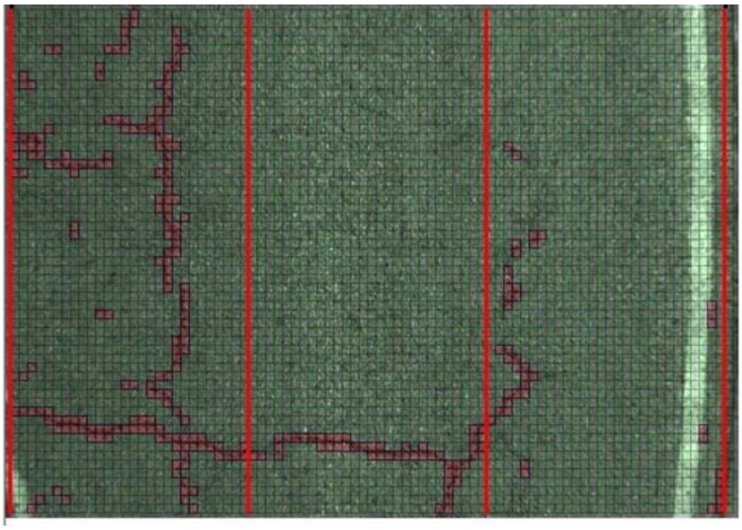

Figure 2. The image tiles of UCI.

Both of the high-speed profiler and PicCrack system can be operated and collect data in 50 km/hr, therefore, when collecting pavement data in city streets, the traffic flow was not affected.

3. METHODOLOGY

PicCrack utilizes area-scan camera mounted on the survey vehicle to collect the pavement images, and with the suited automated distresser the pavement conditions can be evaluated. However, unlike the widely used distress index “Pavement Condition Index (PCI)”, PicCrack system adopts the Unified Crack Index (UCI) concept to quantify the pavement conditions; the calculations and the logics are totally different. When calculating the PCI values, the severity and area of each type of distress is weighted with its corresponding deductive value. To calculate UCI, the image will be divided into tiles and the percentage of “non-cracked and non-patched tiles” are used as UCI value to quantify the condition of the pavement.

The PCI has been adopted as a pavement distress index in Taiwan for years, and also utilized to develop the flow chart of prioritization and the suggested maintenance/rehabilitation activities. Therefore, prior to apply UCI to prioritization, the relationship of UCI and PCI and the benchmark of pavement condition should be discussed.

First of all, the corresponding UCI of present maintenance threshold values (PCI=70 and PCI=40) are calculated. Table 1 and table 2 shows if there is only single severity and type of distress, the corresponding UCI value when PCI=70 and PCI=40. For instance, if there is a road with only medium severity patch, the UCI should be 90.73 when PCI is 70, and the UCI should be 60.67 when PCI is 40. Besides, Table 1 and table 2 also show when comparing with PCI, UCI are higher in most situations.

Table 1 The corresponding UCI value when PCI=70 with single severity and distress type

Severity / Distress type	Low	Medium	High
Alligator Cracking	92.47	97.7	>99
Longitudinal/Transverse Cracking	87.9	96.97	99.27
Patch	63	90.73	97.25
Potholes	98	99.08	>99

* the sample area is 300m^2

Table 2 The corresponding UCI value when PCI=40 with single severity and distress type

Severity / Distress type	Low	Medium	High
Alligator Cracking	11	72.33	86
Longitudinal/Transverse Cracking	0	71.67	96.93
Patch	0	60.67	85.23
Potholes	86.58	96.17	98.53

* the sample area is 300m^2

According to the survey data, potholes are not common seen in the city streets, because the repairing activities for potholes are made immediately. The most common distress in city streets are medium severity patches, and the area of patch is ten to hundred times of the crack. Therefore, take account of the present pavement distress condition of city streets in Taiwan, the medium severity patches are the main deduction in UCI.

Hence, with the regression of present maintenance threshold values (PCI=70 and 40) and the corresponding UCI values in medium severity patch cases, the relationship between PCI and UCI are established (eq.1). Although the concept is similar to switch UCI to PCI, the results are not exactly equal because the equation was established in medium severity patch cases; this equation is used as the benchmark between two indices in most situations. Therefore, the switched result is named Applied Unified Crack Index, AUCI, rather than PCI.

$$AUCI = 0.0083\times(UCI)^2+0.1236\times(UCI) \qquad (eq.1)$$

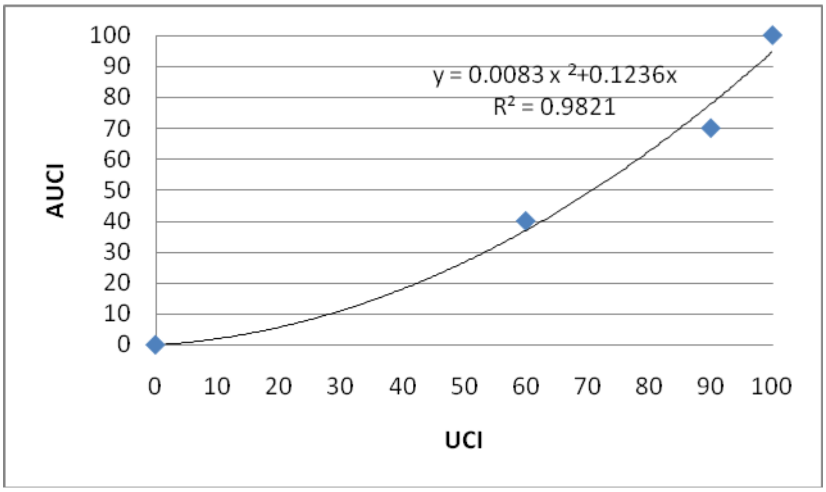

Figure 3. The relationship of UCI and AUCI.

Using present maintenance threshold values PCI=70 and 40 as regression data is to ensure AUCI can sieve out the same maintenance roads, and the corresponding exact PCI value is not so important; therefore, this study adopts only 4 points to regress the equation.

4. RESULT

After converting the UCI to AUCI, the IRI and AUCI data are combined and showed in Figure 4. It is very obvious that there is no correlation between IRI and AUCI, and it also reveals those two indices are not replaceable by each other.

This figure is divided into four sections by the present suggested maintenance thresholds of IRI and PCI; the roads with IRI>400 cm/km should be annual candidate maintenance roads, and the roads with PCI<40 should be rehabilitated. However, this figure shows no matter using single IRI or PCI threshold, some of the roads that should be maintained cannot be sieved.

Therefore, in order to show the real condition of the pavement, both of IRI and AUCI should be considered when prioritizing the maintenance roads. The following are the established pavement maintenance prioritization model for network level.

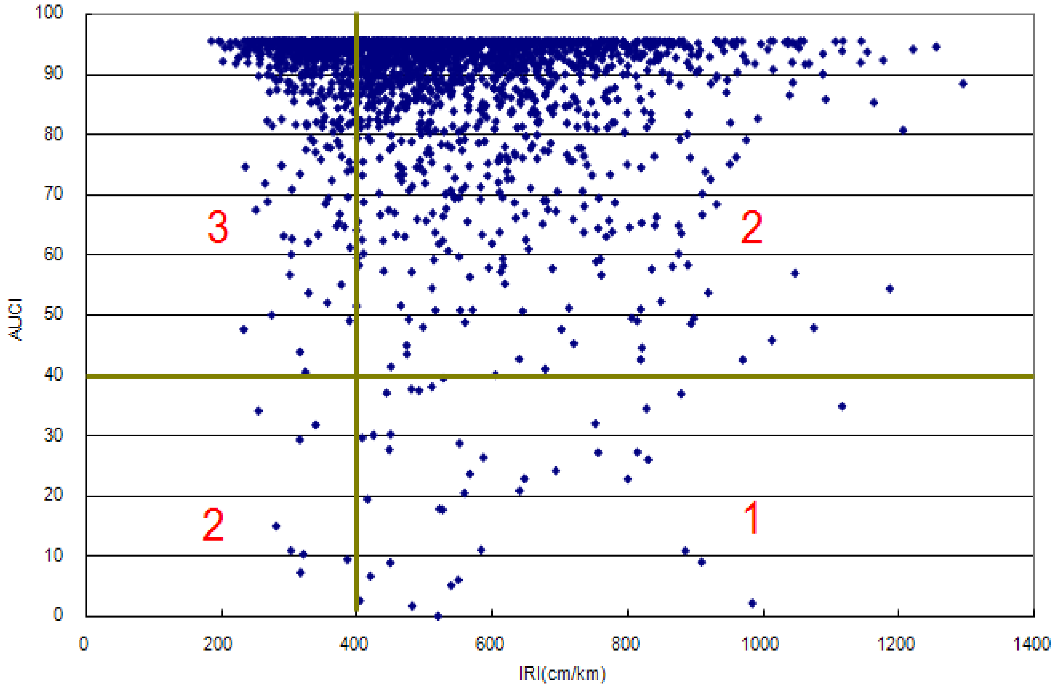

Figure 4. Distribution of IRI and AUCI of the surveyed roads.

Pavement maintenance prioritization model

The objective of the pavement maintenance prioritization model is to combine the IRI and AUCI to evaluate the condition of the road and prioritize it. In addition, the demand of the roads is also considered. Due to the financial problem, rather than considering the historical performance, this model only focuses on the roads which need immediately rehabilitation. The following are the basic assumptions:

1. Mainly consider the rehabilitation.
2. All blocks are independent.
3. The traffic flows of each block are known.
4. Applied to city streets.

The model was established on the basic of the standard of maintenance and management of city streets in Taiwan, which combined PCI and IRI to prioritize the maintenance roads. At first, the pavement surface distress and roughness are converting into Distress Weight "D_j" and Roughness Weight "R_j" (eq.2 and eq.3). The priority weight is calculated by eq.5, and the demand of the road (eq.4) is used to amend the priority. The larger the P_j, represents the condition of the road is worse.

1. Distress Weight (D_j) :

$D_j=1$,when $AUCI_j \leqq 40$

$$D_j = \frac{(100 - AUCI_j)}{60} \quad \text{,when } 40 < AUCI_j \leqq 100 \qquad (eq.2)$$

2. Roughness weight (R_j) :

$R_j=0$,when $IRI_j \leqq 250$

$$R_j = \frac{(IRI_j - 250)}{400} \quad \text{,when } 250 < IRI_j \leqq 650 \qquad (eq.3)$$

$R_j=1.0$,when $IRI_j > 650$

3. Traffic demand of the road :

$$\frac{Vj}{Cj} = \frac{\text{Hourly traffic flow}}{\text{Volume of the lane} \times \text{Number of the lane}} \qquad (eq.4)$$

4. Priority Weight (P_j)

$$P_j = D_j \times R_j \times \left(\frac{V_j}{C_j}\right) \times 100 \qquad (eq.5)$$

The survey data was divided into four sections according to the above prioritizing logic in Figure 5. Section 1 represents the uneven roads with large amount of distress and should be repaired first. Section 2 is composed by 2 parts, one is even roads with larger amount of distress and another is uneven roads with little distress; those roads are insufficient for riding comfort or capability, therefore should be the second priority in maintenance. Section 3 and section 4 represents the roughness and pavement conditions are still acceptable, therefore the priority is lower. However, Figure 5 shows the number of blocks in Section 3 and section 4 is large, so the serviceability of the roads is good.

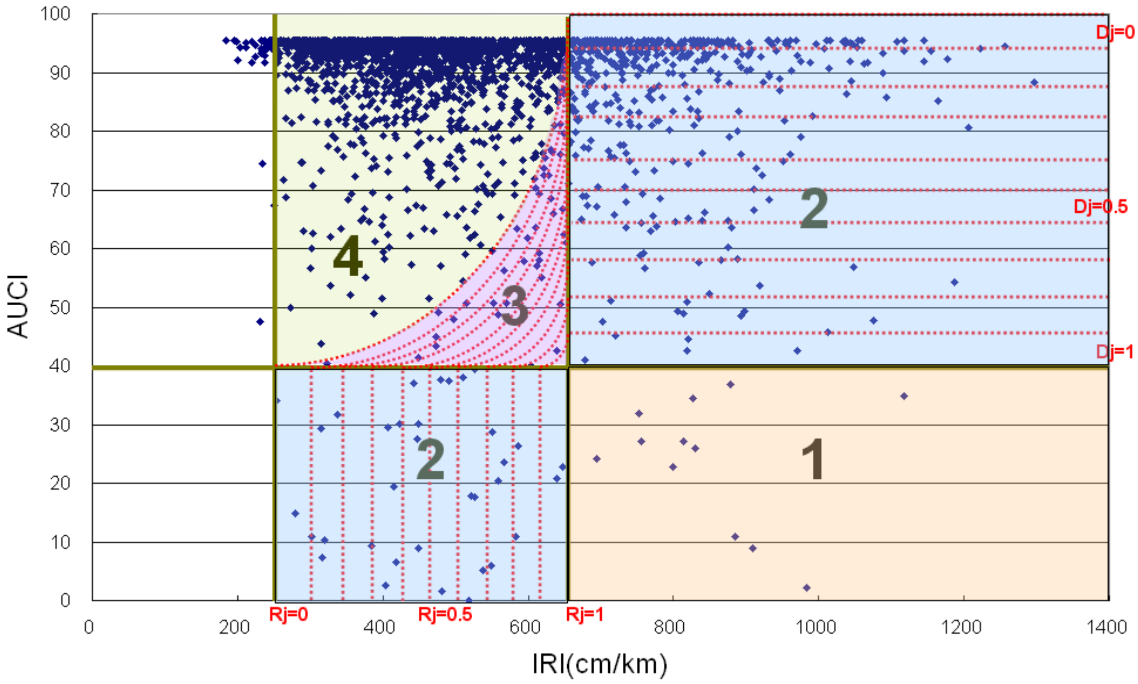

Figure 5 Pavement maintenance prioritization model.

5. CONCLUSION

This study investigated 570 lane-km pavement conditions in city streets with high-speed profiler and automated pavement distress survey system PicCrack synchronously, and the pavement maintenance prioritization for network level is established. Besides, considering the difference between PCI and UCI, the Applied Unified Crack Index (AUCI) was proposed.

The proposed pavement maintenance prioritization model combined AUCI, IRI, and the traffic demand to prioritize the maintenance roads. By multiplying the Distress Weight, Roughness Weight, and traffic demand, the priorities of each road can be estimated easily and quickly. The survey data shows the present serviceability of the roads is still good.

6. ACKNOWLEDGEMENTS

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